Section 2

Waves of the Electromagnetic Spectrum

Objectives

After this lesson, students will be able to

O.3.2.1 Explain how electromagnetic waves are alike and how they are different.

O.3.2.2 Describe the waves that make up the electromagnetic spectrum.

Target Reading Skill

Previewing Visuals Explain that looking at the visuals before they read helps students activate prior knowledge and predict what they are about to read.

Answers

The Electromagnetic spectrum

Which electromagnetic waves have the shortest wavelength? *Gamma rays have the shortest wavelength.*

Which electromagnetic waves have the lowest frequency? *Radio waves have the lowest frequency.*

All in One **Teaching Resources**

- Transparency O30

Preteach

Build Background Knowledge

L2

X-Rays

Guide students in recalling what they already know about X-rays. Ask: **What can you see in an X-ray image?** *(Sample answer: Bones inside the body or teeth inside the jaw)* **What can X-rays pass through?** *(Sample answer: Clothing, skin, muscles)* Explain that X-rays are a type of electromagnetic wave. Tell students they will learn about X-rays and other types of electromagnetic waves in this section.

Section 2

Waves of the Electromagnetic Spectrum

Reading Preview

Key Concepts

- How are electromagnetic waves alike, and how are they different?
- What waves make up the electromagnetic spectrum?

Key Terms

- electromagnetic spectrum
- radio waves • microwaves
- radar • infrared rays
- thermogram • visible light
- ultraviolet rays • X-rays
- gamma rays

Target Reading Skill

Previewing Visuals Before you read, preview Figure 3. Then write two questions that you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

The Electromagnetic Spectrum

Q. Which electromagnetic waves have the shortest wavelength?
A.
Q.

Lab zone Discover Activity

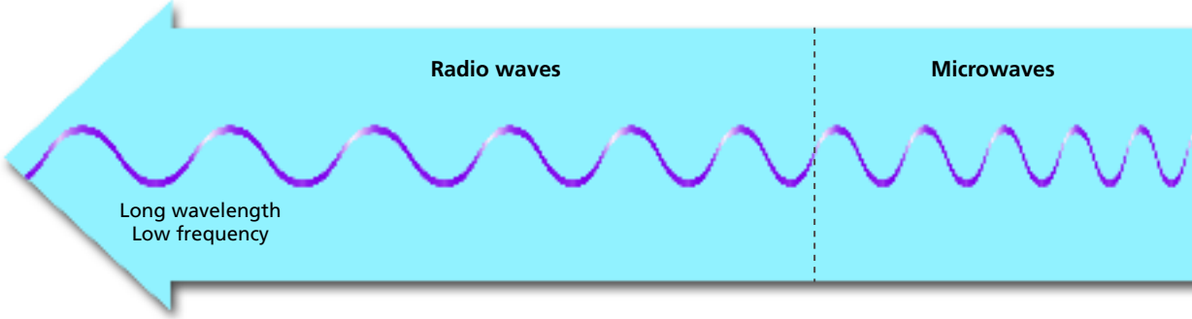
What Is White Light?

1. Line a cardboard box with white paper. Hold a small triangular prism up to direct sunlight. **CAUTION:** *Do not look directly at the sun.*
2. Rotate the prism until the light coming out of the prism appears on the inside of the box as a wide band of colors. Describe the colors and their order.
3. Using colored pencils, draw a picture of what you see inside the box.

Think It Over

Forming Operational Definitions The term *spectrum* describes a range. How is this term related to what you just observed?

Can you imagine trying to take a photo with a radio? How about trying to tune in a radio station on your flashlight or heat your food with X-rays? Light, radio waves, and X-rays are all electromagnetic waves. But each has properties that make it more useful for some purposes and less useful for others. What makes light different from radio waves and X-rays?



Lab zone Discover Activity

Skills Focus Forming operational definitions L1

Materials cardboard box, white paper, prism, colored pencils

Time 15 minutes

Tips Caution students not to look directly at the sun. Student may need some guidance positioning the prism so that the band of colors is visible.

Expected Outcome The prism will form a rainbow inside the box, including the colors red, orange, yellow, green, blue, and violet. Each color will blend into the next.

Think It Over The band of colors shows the range of colors that makes up white light.

What Is the Electromagnetic Spectrum?

All electromagnetic waves travel at the same speed in a vacuum, but they have different wavelengths and different frequencies. Radiation in the wavelengths that your eyes can see is called visible light. But only a small portion of electromagnetic radiation is visible light. The rest of the wavelengths are invisible. Your radio detects radio waves, which have much longer wavelengths than visible light. X-rays, on the other hand, are waves with much shorter wavelengths than visible light.

Recall how speed, wavelength, and frequency are related:

$$\text{Speed} = \text{Wavelength} \times \text{Frequency}$$

Because the speed of all electromagnetic waves is the same, as the wavelength decreases, the frequency increases. Waves with the longest wavelengths have the lowest frequencies. Waves with the shortest wavelengths have the highest frequencies. The amount of energy carried by an electromagnetic wave increases with frequency. The higher the frequency of a wave, the higher its energy.

The **electromagnetic spectrum** is the complete range of electromagnetic waves placed in order of increasing frequency. The full spectrum is shown in Figure 3. **The electromagnetic spectrum is made up of radio waves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays.**

Reading Checkpoint **What is the electromagnetic spectrum?**

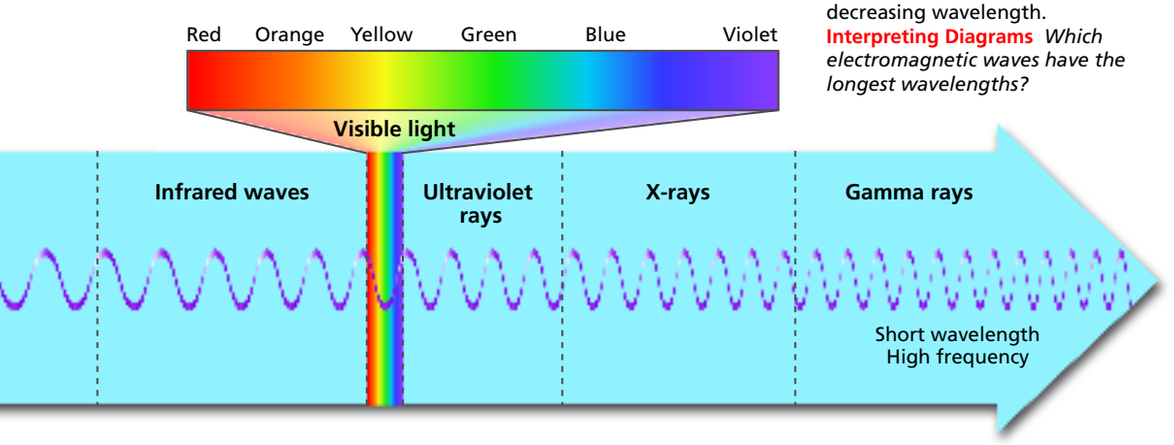


FIGURE 3
The Electromagnetic Spectrum
The electromagnetic spectrum shows the range of different electromagnetic waves in order of increasing frequency and decreasing wavelength.
Interpreting Diagrams *Which electromagnetic waves have the longest wavelengths?*

Differentiated Instruction

Special Needs L1
Diagramming Have students create a diagram of the electromagnetic spectrum similar to Figure 3. The diagram should include a label for each type of electromagnetic wave and a sketch of its relative wavelength and frequency. Students can add details as they read the rest of the section. **learning modality: kinesthetic**

Gifted and Talented L3
Organizing Information Challenge creative students to make a quiz game based on the electromagnetic spectrum by organizing the materials into a series of pertinent questions. The game should require players to know significant facts about the types of electromagnetic waves. Let other students play the games for review. **learning modality: verbal**

Instruct

What Is the Electromagnetic Spectrum?

Teach Key Concepts L2

Speed, Wavelength, and Frequency of Electromagnetic Waves

Focus Read the boldface sentence relating speed, wavelength, and frequency of electromagnetic waves.

Teach Review the formula for wave speed: Speed = Wavelength × Frequency. Remind students that the speed of all electromagnetic waves in a vacuum is the same. Then, ask: **Based on the formula, as the frequency of electromagnetic waves increases, how must their wavelength change? Why?** *(Wavelength must decrease if speed is to remain the same.)*

Apply Tell students that the electromagnetic waves with the highest frequency are called *gamma rays*. Ask: **Which electromagnetic waves have the shortest wavelength?** *(Gamma rays)*
learning modality: logical/mathematical

All in One Teaching Resources
- Transparency O31

Independent Practice L2

All in One Teaching Resources
- Guided Reading and Study Worksheet: *Waves of the Electromagnetic Spectrum*

Student Edition on Audio CD

Monitor Progress L2

Skills Check Have students identify one property all electromagnetic waves have in common and two properties that distinguish types of electromagnetic waves.

Answers
Figure 3 Radio waves

Reading Checkpoint The complete range of electromagnetic waves placed in order of increasing frequency

Radio Waves

Teach Key Concepts L2

Introducing Radio Waves

Focus Introduce radio waves as the type of electromagnetic waves that have the longest wavelengths and lowest frequencies.

Teach Remind students that the frequency of electromagnetic waves determines how much energy they have. Ask: **Are radio waves low-energy or high-energy electromagnetic waves?** *(Low energy)*

Apply Ask: **What are some uses of radio waves?** *(Sample answer: To broadcast radio programs)* Mention uses of microwaves and radar if students do not. **learning modality: verbal**

Address Misconceptions L2

The Speed of Microwaves

Focus Students may think that microwaves travel faster than other radio waves because they have higher frequencies.

Teach State that microwaves, like other radio waves and electromagnetic waves in general, travel at the speed of light, or at about 300,000 km/s. Therefore, all radio waves, including microwaves, take the same amount of time to travel a given distance, regardless of their frequency of vibrations.

Apply Remind students that wave speed is a product of wavelength and frequency. Ask: **How do the wavelengths of microwaves compare with the wavelengths of other radio waves?** *(Microwaves have the shortest wavelengths.)* **learning modality: logical/mathematical**

Lab zone Try This Activity

Microwave Test

In this activity, you will compare how water, corn oil, and sugar absorb microwaves.

1. Add 25 mL of water to a glass beaker. Record the temperature of the water.
2. Microwave the beaker for 10 seconds and record the water temperature again.
3. Repeat Steps 1 and 2 two more times, using 25 mL of corn oil and 25 mL of sugar.

Drawing Conclusions
Compare the temperature change of the three materials. Which material absorbed the most energy from the microwaves?

Radio Waves

Radio waves are the electromagnetic waves with the longest wavelengths and lowest frequencies. They include broadcast waves (for radio and television) and microwaves.

Broadcast Waves Radio waves with longer wavelengths are used in broadcasting. They carry signals for both radio and television programs. A broadcast station sends out radio waves at certain frequencies. Your radio or TV antenna picks up the waves and converts the radio signal into an electrical signal. Inside your radio, the electrical signal is converted to sound. Inside your TV, the signal is converted to sound and pictures.

Microwaves The radio waves with the shortest wavelengths and the highest frequencies are **microwaves.** When you think of microwaves, you probably think of microwave ovens that cook and heat your food. But microwaves have many uses, including cellular phone communication and radar.

Radar stands for **ra**dio **d**etection **a**nd **r**anging. **Radar** is a system that uses reflected radio waves to detect objects and measure their distance and speed. To measure distance, a radar device sends out radio waves that reflect off an object. The time it takes for the reflected waves to return is used to calculate the object's distance. To measure speed, a radar device uses the Doppler effect, which you learned about in Chapter 2. For example, a police radar gun like the one in Figure 4 sends out radio waves that reflect off a car. Because the car is moving, the frequency of the reflected waves is different from the frequency of the original waves. The difference in frequency is used to calculate the car's speed.

Reading Checkpoint **What does *radar* stand for?**

FIGURE 4
Radar Gun
Radio waves and the Doppler effect are used to find the speeds of moving vehicles.

Lab zone Try This Activity

Skills Focus Drawing conclusions L2

Materials glass beaker; 25 mL each of water, corn oil, and sugar; thermometer; microwave oven

Time 15 minutes

Tips Clean and dry the beaker after each test. Caution students to wear goggles and heat-resistant gloves, and to be careful handling glassware.

Expected Outcome The water will have the greatest increase in temperature, followed by the corn oil, and then the sugar. Students are expected to conclude that the water absorbed the most energy.

Extend Ask students to predict how much energy some other substances might absorb from microwaves. Let them test their predictions. **learning modality: kinesthetic**

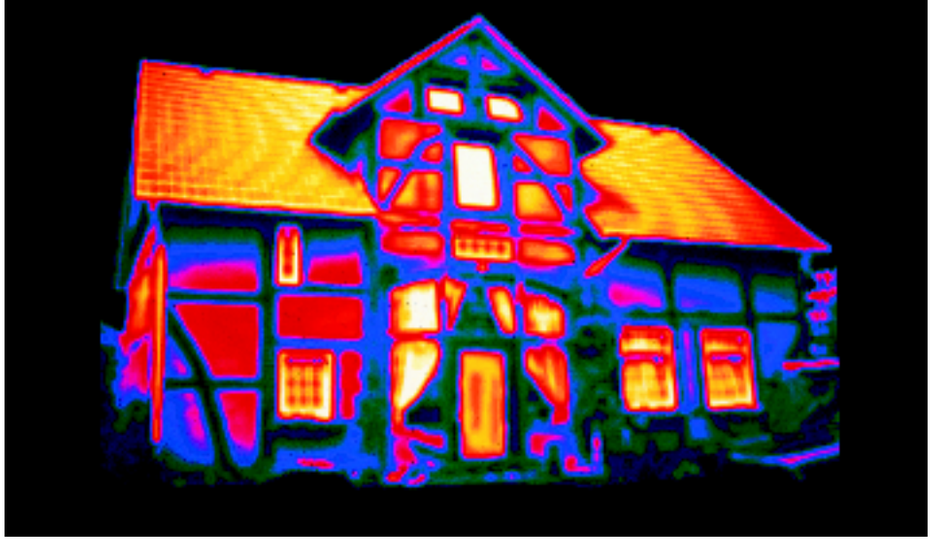


FIGURE 5
Infrared Images
An infrared camera produced this image, called a thermogram. Regions of different temperatures appear in different colors.
Interpreting Photographs *Which areas of the house are warmest (color-coded white)? Which are coolest (color-coded blue)?*

Infrared Rays

If you turn on a burner on an electric stove, you can feel it warm up before the heating element starts to glow. The invisible heat you feel is infrared radiation, or infrared rays. **Infrared rays** are electromagnetic waves with wavelengths shorter than those of radio waves.

Heat Lamps Infrared rays have a higher frequency than radio waves, so they have more energy than radio waves. Because you can feel the energy of infrared rays as heat, these rays are often called heat rays. Heat lamps have bulbs that give off mostly infrared rays and very little visible light. These lamps are used to keep food warm at a cafeteria counter. Some people use heat lamps to warm up their bathrooms quickly.

Infrared Cameras Most objects give off some infrared rays. Warmer objects give off infrared waves with more energy and higher frequencies than cooler objects. An infrared camera takes pictures using infrared rays instead of light. These pictures are called thermograms. A **thermogram** is an image that shows regions of different temperatures in different colors. Figure 5 shows a thermogram of a house. You can use an infrared camera to see objects in the dark. Firefighters use infrared cameras to locate fire victims inside a dark or smoky building. Satellites in space use infrared cameras to study the growth of plants and the motions of clouds.

Reading Checkpoint **What is recorded by an infrared camera?**

Differentiated Instruction

Less Proficient Readers L1
Taking Notes on Electromagnetic Waves Suggest to students that they write the name of each type of electromagnetic wave on one side of an index card. On the other side of the cards, they can list important details about the types of electromagnetic waves as they read about them in this section. **learning modality: verbal**

Gifted and Talented L3
Researching Uses Infrared Waves Ask interested students to learn more about a use of infrared cameras and thermograms that is mentioned in the text. For example, students might research how these tools are used by biologists to study plant growth from space. Urge students to share what they learn in an oral report. **learning modality: verbal**

Infrared Rays

Teach Key Concepts L2

Properties of Infrared Rays

Focus Remind students that infrared rays are next to radio waves in the electromagnetic spectrum.

Teach Ask: **Which have higher frequencies, radio waves or infrared waves?** *(Infrared)* **Which have more energy?** *(Infrared)* Tell students that infrared rays are often called heat rays because you can feel their energy as heat.

Apply Ask: **Why does sunlight feel warm on your skin?** *(Sample answer: Because it contains infrared waves)* **learning modality: verbal**

Lab zone **Build Inquiry** L2

Observing Infrared Rays

Materials warm tap water, hot tap water, 2 plastic foam cups, thermometer, metric ruler

Time 5 minutes

Focus State that most objects give off some infrared rays.

Teach Have students fill one cup with warm tap water and the other cup with hot tap water. Then, have students measure the greatest distance at which they can feel heat from each cup. Ask: **Which cup's heat can you feel a greater distance?** *(The cup containing hot water)*

Apply Ask: **What can you conclude about the temperature of objects and the infrared rays they emit?** *(Sample answer: The higher the temperature of an object, the stronger the infrared rays it gives off.)* **learning modality: kinesthetic**

Monitor Progress L2

Oral Presentation Call on students to state how radio and infrared waves are used.

Answers

Figure 5 The windows and edges of the roof appear to be the warmest areas, and the wooden frame appears to be the coolest area.

Reading Checkpoint Radio detection and ranging

Reading Checkpoint Infrared rays, which are used to make a thermogram

Visible Light

Teach Key Concepts L2

Wavelengths and Frequencies of Visible Light

Focus Have students shut their eyes tightly for a few seconds before opening them again. Then, tell students that the difference between what they see with their eyes shut and their eyes open is due to visible light.

Teach Refer students to Figure 3 at the beginning of this section, and have them identify the place of visible light in the electromagnetic spectrum. Ask: **Which type of electromagnetic waves have a shorter wavelength and higher frequency, visible light or infrared rays?** *(Visible light)* **Within the range of visible light, which color of light has the shortest wavelength and highest frequency?** *(Violet)* Now, refer students to Figure 6. Ask: **What color does visible light appear when all its wavelengths are combined?** *(White)* **How can visible light of different wavelengths be separated to produce light of different colors?** *(By passing white light through a prism)*

Apply Ask: **How does a prism separate white light into its separate colors?** *(By bending, or refracting, light of different wavelengths by different amounts)* **learning modality: visual**

Ultraviolet Rays

Teach Key Concepts L2

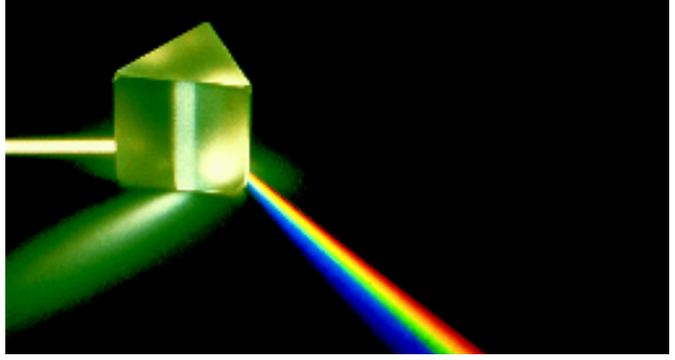
Recalling Knowledge About Ultraviolet Rays

Focus Guide students in recalling what they already know about ultraviolet rays.

Teach Explain that ultraviolet rays are often called UV rays. Then, ask: **What are some products that have phrases such as "UV protection" or "UV block" on their labels?** *(Sample answer: Sunblock, skin lotion, makeup, some types of clothing, sunglasses)* **Why do people need to be protected from ultraviolet rays?** *(Sample answer: Because they can cause skin cancer)*

Apply Ask: **Do ultraviolet rays have more or less energy than visible light?** *(More energy)* **How do you know?** *(Because they have higher frequencies)* **learning modality: verbal**

FIGURE 6
Refraction in a Prism
When white light passes through a prism, refraction causes the light to separate into its wavelengths.
Observing *Which color of light is refracted the least?*



Visible Light

Electromagnetic waves that you can see are called **visible light.** They make up only a small part of the electromagnetic spectrum. Visible light waves have shorter wavelengths and higher frequencies than infrared rays. Visible light waves with the longest wavelengths appear red in color. As the wavelengths decrease, you can see other colors of light. The shortest wavelengths of visible light appear violet in color.

Visible light that appears white is actually a mixture of many colors. White light from the sun can be separated by a prism into the colors of the visible spectrum—red, orange, yellow, green, blue, and violet. Recall that when waves enter a new medium, the waves bend, or refract. The prism refracts different wavelengths of visible light by different amounts and thereby separates the colors. Red light waves refract the least. Violet light waves refract the most.

Ultraviolet Rays

Electromagnetic waves with wavelengths just shorter than those of visible light are called **ultraviolet rays.** Ultraviolet rays have higher frequencies than visible light, so they carry more energy. The energy of ultraviolet rays is great enough to damage or kill living cells. In fact, ultraviolet lamps are often used to kill bacteria on hospital equipment.

Small doses of ultraviolet rays are useful. For example, ultraviolet rays cause skin cells to produce vitamin D, which is needed for healthy bones and teeth. However, too much exposure to ultraviolet rays is dangerous. Ultraviolet rays can burn your skin, cause skin cancer, and damage your eyes. If you apply sunblock and wear sunglasses that block ultraviolet rays, you can limit the damage caused by ultraviolet rays.

Reading Checkpoint **How can ultraviolet rays be useful?**

Math Skills

Scientific Notation

Frequencies of waves often are written in scientific notation. A number in scientific notation consists of a number between 1 and 10 that is multiplied by a power of 10. To write 150,000 Hz in scientific notation, move the decimal point left to make a number between 1 and 10:

150,000 Hz

In this case, the number is 1.5. The power of 10 is the number of spaces you moved the decimal point. In this case, it moved 5 places, so

$150{,}000 \text{ Hz} = 1.5 \times 10^5 \text{ Hz}$

Practice Problem A radio wave has a frequency of 5,000,000 Hz. Write this number in scientific notation.

Math Skills

Math Skill Scientific notation

Answer 5.0×10^6 Hz

X-Rays

X-rays are electromagnetic waves with wavelengths just shorter than those of ultraviolet rays. Their frequencies are just a little higher than ultraviolet rays. Because of their high frequencies, X-rays carry more energy than ultraviolet rays and can penetrate most matter. But dense matter, such as bone or lead, absorbs X-rays and does not allow them to pass through. Therefore, X-rays are used to make images of bones inside the body or of teeth, as shown in Figure 7. X-rays pass through skin and soft tissues, causing the photographic film in the X-ray machine to darken when it is developed. The bones, which absorb X-rays, appear as the lighter areas on the film.

Too much exposure to X-rays can cause cancer. If you've ever had a dental X-ray, you'll remember that the dentist gave you a lead apron to wear during the procedure. The lead absorbs X-rays and prevents them from reaching your body.

X-rays are sometimes used in industry and engineering. For example, to find out if a steel or concrete structure has tiny cracks, engineers can take an X-ray image of the structure. X-rays will pass through tiny cracks that are invisible to the human eye. Dark areas on the X-ray film show the cracks. This technology is often used to check the quality of joints in oil and gas pipelines.

Reading Checkpoint **What kind of matter blocks X-rays?**

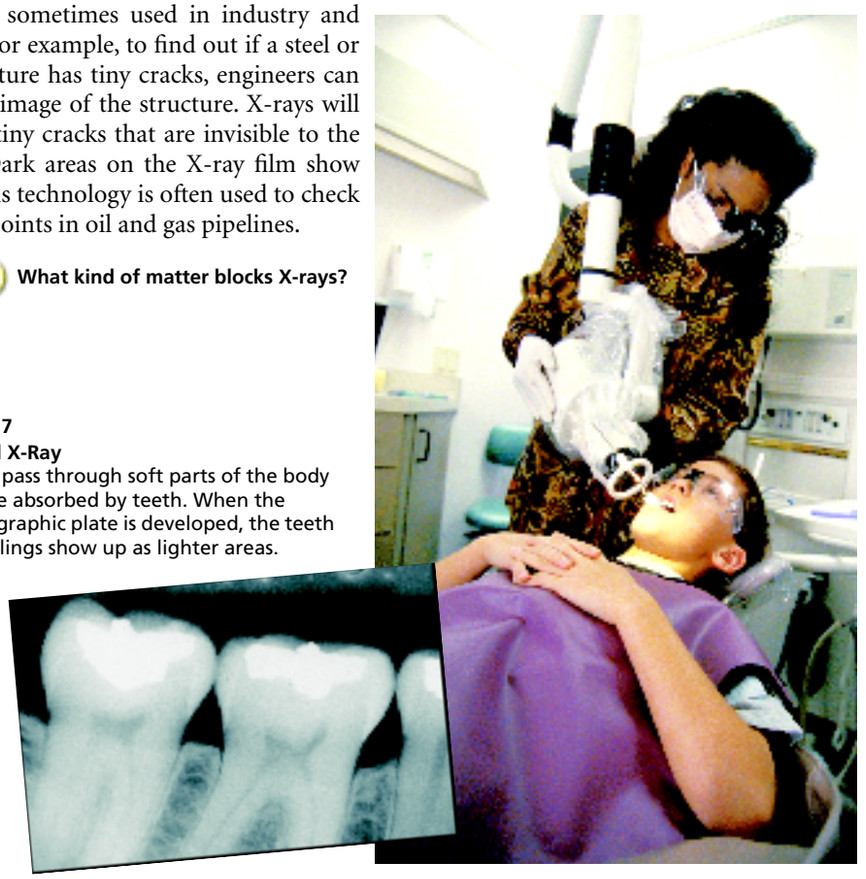


FIGURE 7
Dental X-Ray
X-rays pass through soft parts of the body but are absorbed by teeth. When the photographic plate is developed, the teeth and fillings show up as lighter areas.

X-Rays

Teach Key Concepts L2

Observing X-Ray Images

Focus Discuss X-ray images, which will be familiar to most students.

Teach Ask: **What type of matter appears white in the X-ray in Figure 7?** *(Bones)* Explain that bones appear white because they absorb X-rays. Ask: **What tissues did the X-rays pass through to make this image?** *(Skin, muscle, blood)*

Apply Ask: **Why would a break in a bone appear as a dark line on the bone in an X-ray image?** *(Because X-rays pass through the crack in the bone instead of being absorbed)* **learning modality: visual**

Lab zone Build Inquiry L2

Modeling X-rays and Other Electromagnetic Waves

Materials phone book, cardboard, tissue paper, cotton ball, dull pencil, push pin

Time 15 minutes

Focus Students will model how electromagnetic waves penetrate matter.

Teach Have students make a stack with the phone book on the bottom and the paper on top. The other materials represent types of electromagnetic waves. Have students press each material into the top of the stack and observe how it affects the layers. Then, ask: **In its energy and ability to penetrate matter, which object best represents X-rays?** *(The pin)* **Which type of electromagnetic waves might the dull pencil and cotton ball represent?** *(Sample answer: ultraviolet rays, and infrared rays, respectively)*

Apply Ask: **If the paper and cardboard represent skin and muscle, what might the book represent?** *(Bones or teeth)* **learning modality: kinesthetic**

Differentiated Instruction

English Learners/Beginning L1
Comprehension: Modified Cloze
Distribute a simplified version of the first paragraph about X-rays. Leave some of the important terms blank. Provide students with a list of the answers, and have them fill in each blank with one of the words on the list. Show how to fill in the blanks with a model sentence. **learning modality: visual**

English Learners/Intermediate L2
Vocabulary: Writing Have students use the names of the different electromagnetic waves in sentences. Tell them to find and read the sentence in which each name appears in boldface and also a few of the sentences around it. Then, they can write an original sentence containing the word. Show them how, using radio waves as an example. **learning modality: verbal**

Monitor Progress L2

Oral Presentation Ask students to identify uses of ultraviolet rays and X-rays.

Answers

Figure 6 Red light is refracted the least.

Reading Checkpoint They can kill bacteria and help skin produce vitamin D.

Reading Checkpoint Dense matter, such as bone or lead

Help Students Read

L1

Relating Text and Figures Have students read the captions and study the drawings in Figure 8, which summarizes how the different types of electromagnetic waves affect people's lives. Then, ask students questions about each type of wave and its stated use or effect that require them to integrate information from the text. For example, ask: **Would you expect a television station to broadcast low-frequency or high-frequency electromagnetic waves?** *(Low frequency)* **Which of the two types of electromagnetic waves that can be used to cook food has shorter wavelengths?** *(Infrared rays)* **Why are ultraviolet rays more dangerous than visible light?** *(Ultraviolet rays have higher frequencies and therefore more energy than visible light, so they are more penetrating.)* If students are unable to answer any of the questions, have them reread the relevant parts of the section to find the answers.

Go Online active art

For: Electromagnetic Waves activity
Visit: PHSchool.com
Web Code: cgp-5032

Students can interact with the art of electromagnetic waves online.

All in One Teaching Resources

- Transparency O32

Gamma Rays

Teach Key Concepts

L2

Predicting Properties of Gamma Rays

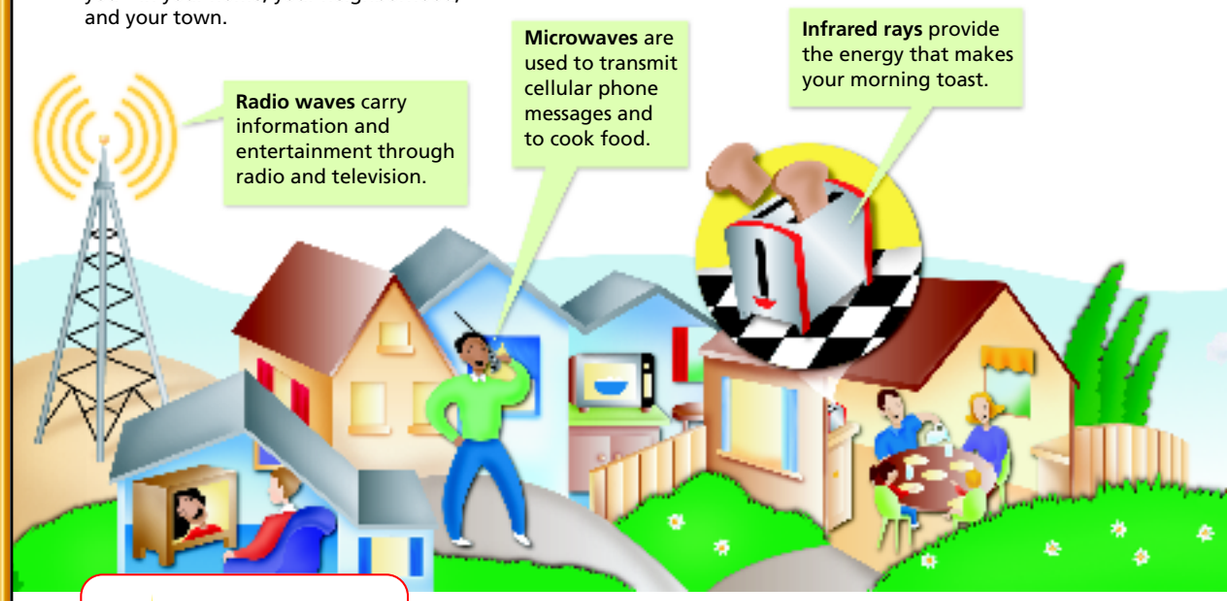
Focus Guide students in using what they already know about the rest of the electromagnetic spectrum to predict properties of gamma rays.

Teach State that gamma rays are the electromagnetic waves with the highest frequencies. Ask: **How do the wavelengths of gamma rays compare with those of other electromagnetic waves?** *(Gamma rays have the shortest wavelengths.)* **How much energy do gamma rays have compared with other types of electromagnetic waves?** *(More than any other type)* **What types of matter do you think gamma rays might be able to penetrate?** *(Sample answer: Bones, teeth, or lead)* Confirm that gamma rays can penetrate most types of matter.

FIGURE 8

Electromagnetic Waves

Electromagnetic waves are all around you—in your home, your neighborhood, and your town.



Go Online active art

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Gamma Rays

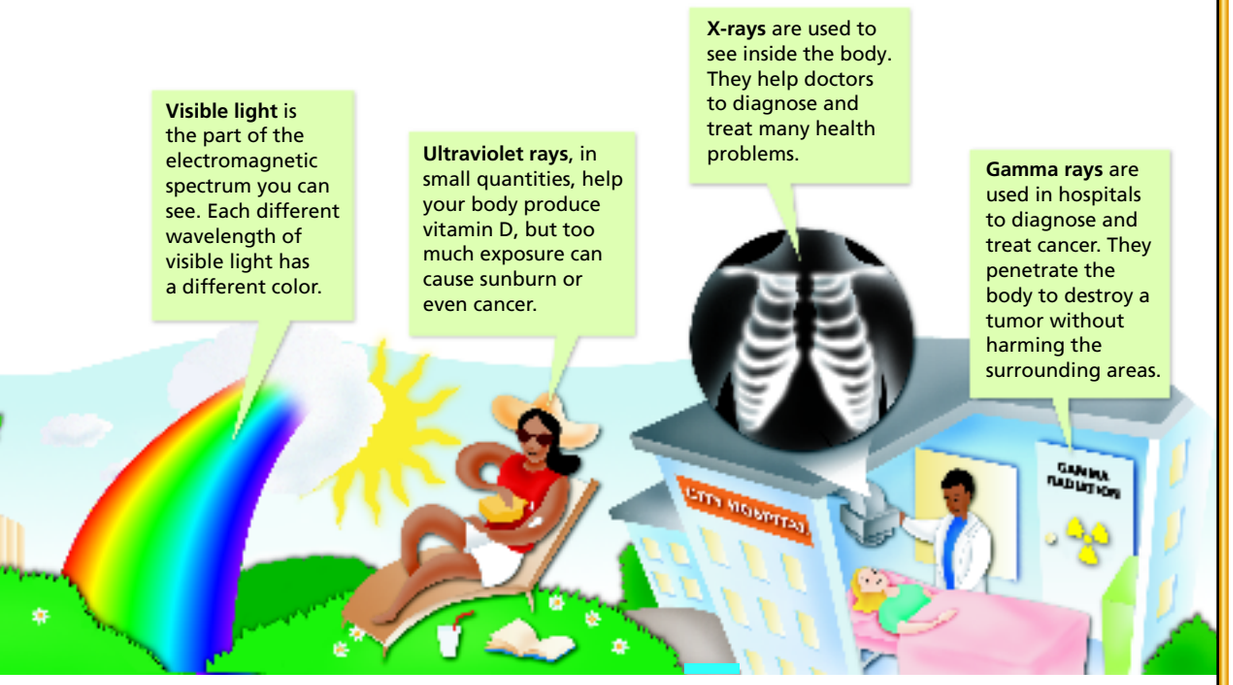
Gamma rays are the electromagnetic waves with the shortest wavelengths and highest frequencies. Because they have the greatest amount of energy, gamma rays are the most penetrating of all the electromagnetic waves.

Some radioactive substances and certain nuclear reactions produce gamma rays. Because of their great penetrating ability, gamma rays have some medical uses. For example, gamma rays can be used to kill cancer cells inside the body. To examine the body's internal structures, a patient can be injected with a fluid that emits gamma rays. Then a gamma-ray detector can form an image of the inside of the body.

Some objects in space give off bursts of gamma rays. The gamma rays are blocked by Earth's atmosphere, so gamma-ray telescopes that detect them must orbit above Earth's atmosphere. Astronomers think that explosions of stars in distant galaxies are one way of producing these gamma rays.

Reading Checkpoint **How are gamma rays produced?**

Apply Point out that gamma rays can be used to kill cancer cells and create images of the inside of the body. **learning modality: verbal**



Section 2 Assessment

Target Reading Skill **Previewing Visuals** Refer to your questions and answers about Figure 3 to help you answer Question 2 below.

Reviewing Key Concepts

1. a. **Reviewing** What is the mathematical relationship among wavelength, frequency, and speed?
   b. **Summarizing** In what way are all electromagnetic waves the same? In what ways are they different?
   c. **Making Generalizations** As the wavelengths of electromagnetic waves decrease, what happens to their frequencies? To their energies?
2. a. **Listing** List the waves in the electromagnetic spectrum in order from lowest frequency to highest frequency.
   b. **Explaining** Why are some electromagnetic waves harmful to you but others are not?
   c. **Classifying** List one or more types of electromagnetic waves that are useful for each of these purposes: cooking food, communication, seeing inside the body, curing diseases, reading a book, warming your hands.

Math Practice

Scientific Notation

3. An FM radio station broadcasts at a frequency of 9×10^5 Hz. Write the frequency as a number without an exponent.
4. Red light has a frequency of 4×10^{14} Hz. Express the frequency without using an exponent.

Math Practice

Math Skill Scientific notation

Answers

1. 900,000 Hz
2. 400,000,000,000,000 Hz (400 trillion Hz)

Lab zone Chapter Project

Keep Students on Track By now, students should have completed their list of survey questions. Advise students to limit their number of survey questions. When students distribute their surveys, they should tell respondents when to return the completed surveys.

Monitor Progress L2

Answer

Reading Checkpoint Gamma rays are produced by some radioactive substances and certain nuclear reactions. Some objects in space give off gamma rays.

Assess

Reviewing Key Concepts

1. a. Speed = Wavelength × Frequency
b. All electromagnetic waves travel at the same speed in a vacuum, but they have different wavelengths and frequencies.
c. As wavelengths decrease, frequencies and energies increase.
2. a. Radio waves, infrared rays, visible light, ultraviolet rays, X-rays, gamma rays
b. High-frequency waves (ultraviolet rays, X-rays, and gamma rays) can penetrate matter and cause damage because they have high energy. Low-frequency waves (radio waves, infrared rays, and visible light) have less energy and are less likely to cause harm.
c. Cooking food: microwaves and infrared rays; communication: radio waves and microwaves; seeing inside the body: X-rays and gamma rays; curing diseases: gamma rays; reading a book: visible light; warming your hands, infrared rays

Reteach L1

Call on students to name the types of electromagnetic waves in order from lowest to highest frequencies. Call on other students to state a property, use, or effect of each type of wave. Correct any errors.

Performance Assessment L2

Skills Check Ask students to make a table comparing and contrasting the different types of electromagnetic waves. Students can keep their tables in their portfolios.

Portfolio

All in One Teaching Resources

- Section Summary: *Waves of the Electromagnetic Spectrum*
- Review and Reinforcement: *Waves of the Electromagnetic Spectrum*
- Enrich: *Waves of the Electromagnetic Spectrum*

Technology and Society

Microwave Ovens

Key Concept

Using microwave ovens has made preparing food faster and easier than using conventional ovens. However, microwave ovens also have drawbacks that require users to follows safety guidelines.

Build Background Knowledge

Advantages of Microwave Ovens

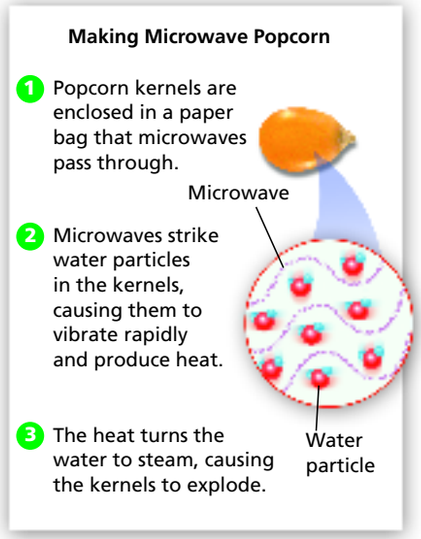
Guide students in recognizing the convenience of using microwave ovens. Ask: **What foods do you heat or cook in a microwave oven?** *(Sample answers: Popcorn, soup, frozen pizzas and dinners, frozen pancakes and pastries, leftovers)* **How would you heat or cook these foods if you did not have a microwave oven?** *(Sample answers: These foods can be cooked using conventional ovens, stovetops, or other cooking methods.)* **Which method of heating and cooking food is generally faster and easier?** *(Sample answer: Microwave ovens generally make heating and cooking food faster and easier.)*

Introduce the Debate

Have students read about the drawbacks of microwave ovens in the feature. Explain that microwaves, like other radio waves, cannot be seen, heard, or felt. Ask: **Why do these properties of microwaves make them even more dangerous?** *(Sample answer: Because you cannot tell if you are being exposed to microwaves)* **Do you think the advantages of microwaves outweigh the drawbacks?** *(Students may say yes or no.)*

Microwave Ovens

In 1946, as Dr. Percy Spencer worked on a radar device that produced microwaves, a candy bar melted in his pocket. Curious, he put some popcorn kernels near the device—they popped within minutes. Then, he put an egg near the device. It cooked so fast that it exploded. Dr. Spencer had discovered a new way of cooking food quickly. The microwave-oven industry was born.



Cooking With Microwaves

How do microwave ovens cook food? The answer lies in the way microwaves are reflected, transmitted, and absorbed when they strike different types of materials, such as food, metal, and plastic. In a microwave oven, microwaves reflect off the inner metal walls, bouncing around in the cooking chamber. They mostly pass right through food-wrapping materials such as plastic, glass, and paper. But foods absorb microwaves. Within seconds, the energy from the absorbed microwaves causes water and fat particles in the foods to start vibrating rapidly. These vibrations produce the heat that cooks the food.

Faster Cooking, But Is It Safe?

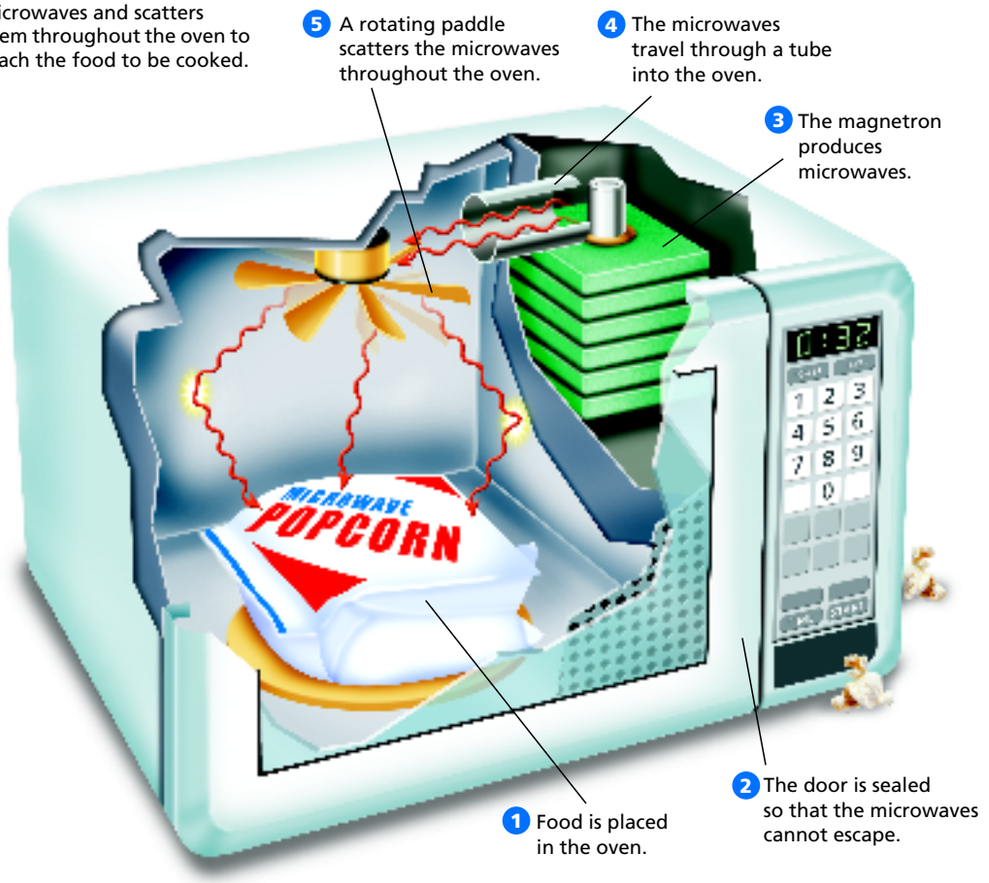
Using microwave ovens has made preparing food faster and easier than using conventional ovens. But, using microwave ovens has drawbacks. Overheating liquids in a microwave oven can cause the liquids to boil over or can cause serious burns. Also, microwave ovens can cook foods unevenly. This can result in foods being undercooked. Health risks can result from not cooking some foods, such as meats and poultry, thoroughly.

Facilitate the Debate

- Ask students to read the rest of the feature and answer the first Weigh the Impact question.
- As a homework or computer lab assignment, direct students to do the research in question 2 on microwave technology guidelines and user safety measures.
- After students have completed their research, divide the class into two groups. Assign one group to argue that microwave ovens are easy and safe for anyone to use. Assign the other group to argue that microwave ovens are potentially dangerous and should be used only if proper safety measures are followed.
- Give members of each groups a chance to discuss the issue and make a list of points to support their side of the argument. Each group should then elect one student to express the group's views in the debate.

How a Microwave Oven Works

A microwave oven produces microwaves and scatters them throughout the oven to reach the food to be cooked.



Weigh the Impact

1. Identify the Need
What advantages do microwave ovens have over conventional ovens?

2. Research
The U.S. Food and Drug Administration (FDA) regulates safety issues for microwave ovens. Research microwave ovens on the Internet to find FDA guidelines about this technology. What safety measures does the FDA recommend?

3. Write
Based on your research, create a poster showing how to use microwave ovens safely. With your teacher's permission, display your poster in the school cafeteria.

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Background

Facts and Figures In a microwave oven, an electronic device, called a magnetron, produces an oscillating beam of microwaves that changes direction millions of times per second. These oscillations cause water molecules in food to vibrate. The vibrations produce heat, which cooks the food.

High densities of microwave radiation can cause serious health problems. Microwave ovens use low levels of microwaves, but leakage of microwaves may be dangerous for people nearby if they are exposed over a long period. Although it is not yet known if long-term exposure to low levels of microwaves is dangerous, the U.S. government limits exposure to microwaves in general to 10 milliwatts/cm^2 and places stricter limits on microwave ovens.

Weigh the Impact

1. Microwave ovens heat or cook food in much less time than conventional ovens. Using microwave ovens makes preparing food faster and easier than using conventional ovens.
2. The FDA limits the amount of microwaves that can leak from an oven in its lifetime to 5 milliwatts/cm^2 (at a distance of 5 cm). This is well below the level of microwave exposure known to be dangerous.
3. Posters should incorporate FDA safety tips for consumers, which include: follow the manufacturer's instruction manual for recommended operating procedures and safety precautions for your oven model; do not operate a microwave oven if the door does not close firmly or is damaged; never operate a microwave oven if you think it might continue to operate with the door open; do not stand directly against a microwave oven for long periods of time while it is operating; do not heat water or liquids in the microwave oven for excessive amounts of time. Posters should be illustrated and easy to read from a distance. Students might organize the safety recommendations under headings, such as: Where Should I Stand When Using a Microwave Oven? When Is a Microwave Oven Not Safe to Use?

All in One Teaching Resources

- Transparency O33

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Students can research microwave ovens online.

Extend

Tell students that some microwaves have a rotating plate where the food is placed. Ask: **How does constantly rotating the food in a microwave oven help overcome one of its drawbacks?** *(Sample answer: Microwave ovens can cook foods unevenly. Rotating the food helps to cook it more evenly.)*